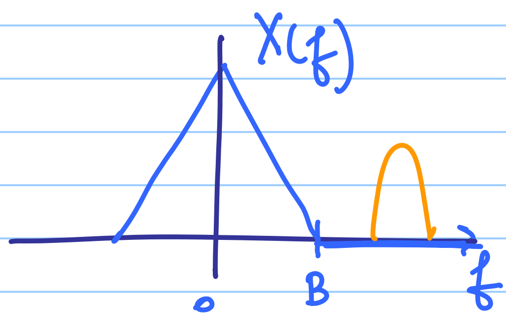
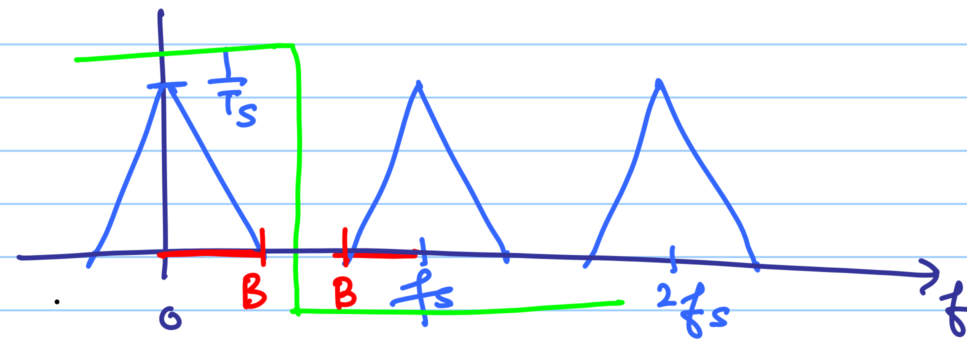
ECE 517 - Lecture 2

Note Title 1/17/2017



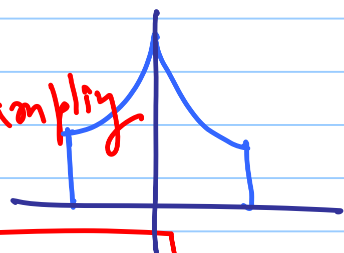
Ideal Sampling $\longrightarrow$

Sample rate $= f_s$



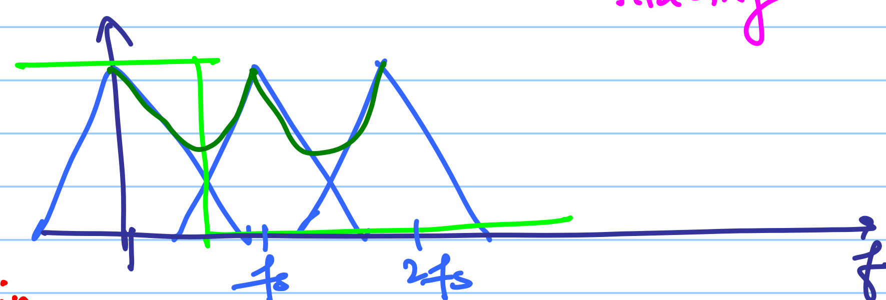
Aliasing

Nyquist Sampling Theorem

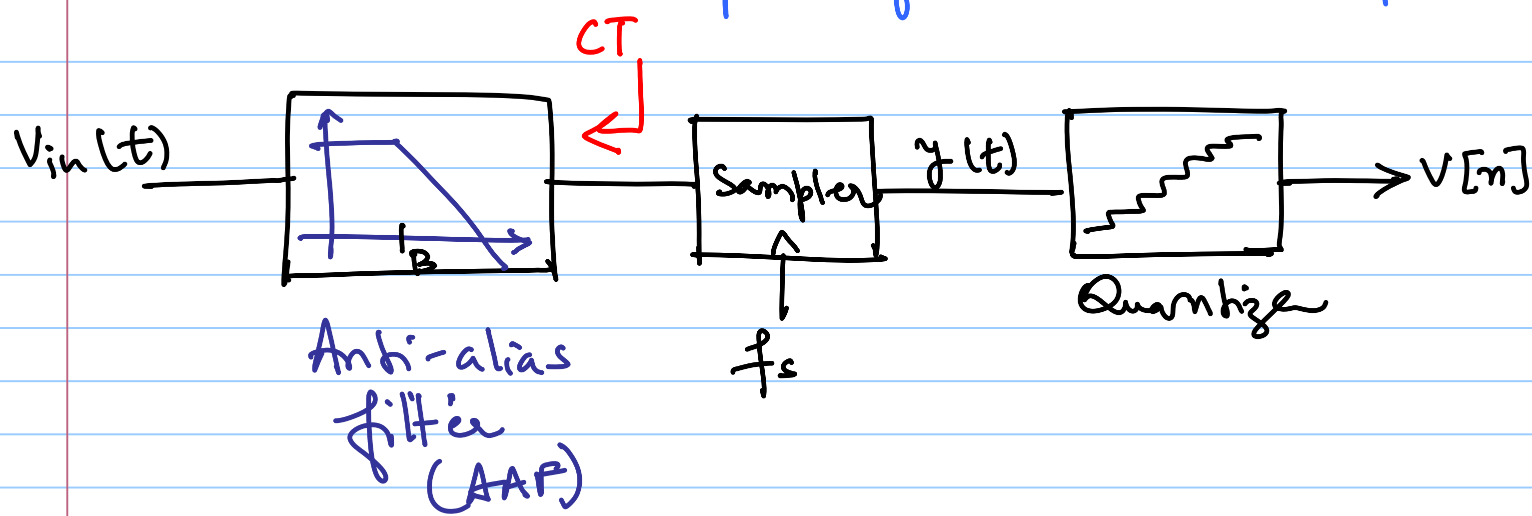


$$\boxed{f_s \geq 2B}$$

Aliasing



* Bandlimit the input signal to the sampler

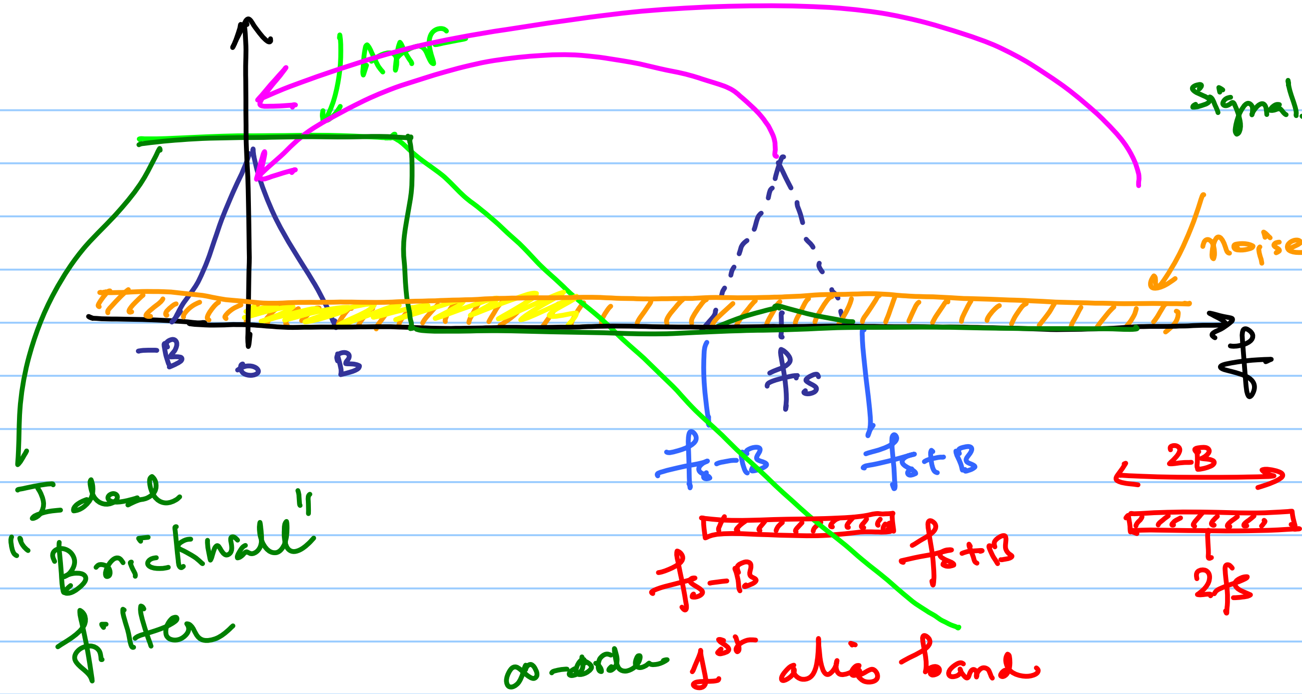


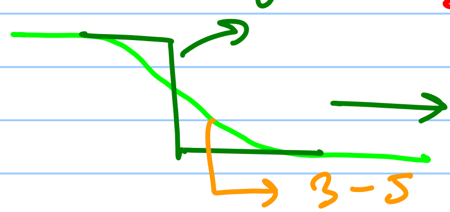
↳ AAF is always a continuous-time filter

↳ can't use switched capacitor type filter

Discrete-time circuits

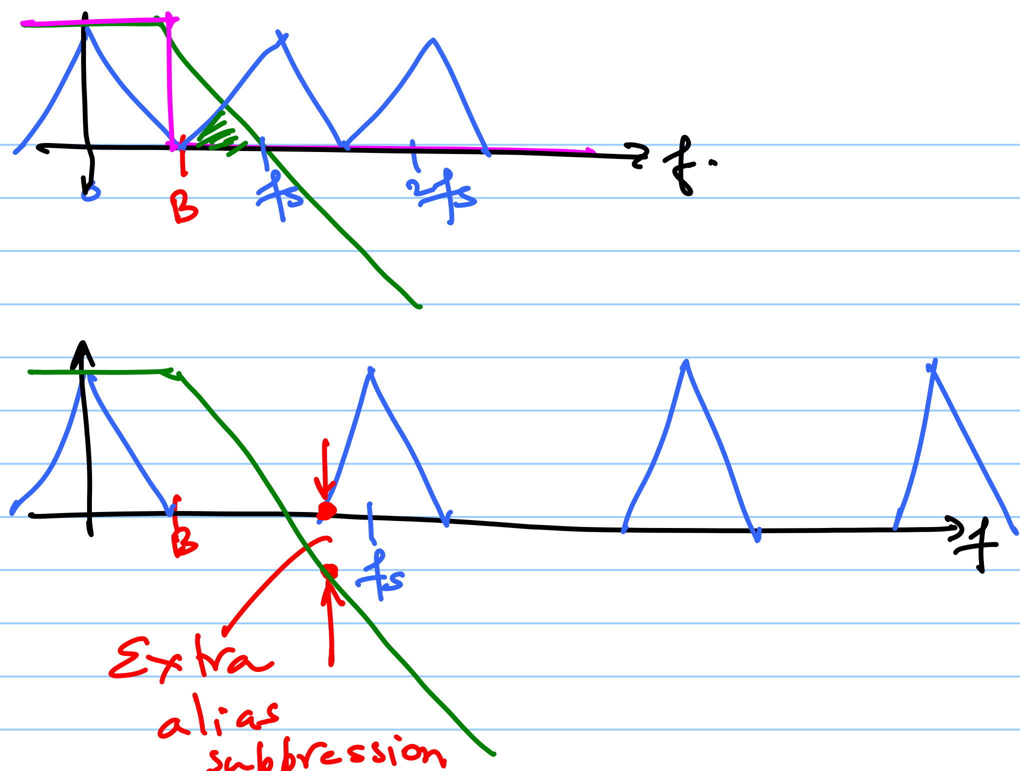
AAF suppresses the noise & signals in the alias bands





→ ∞ number of circuit stages

↳ power hungry



$f_s = 2B$

Nyquist sampling rate

$f_s = \underline{4B}$ ← OSR=2

oversampling

$f_s = \text{OSR} \times f_{s,\text{Nyquist}}$

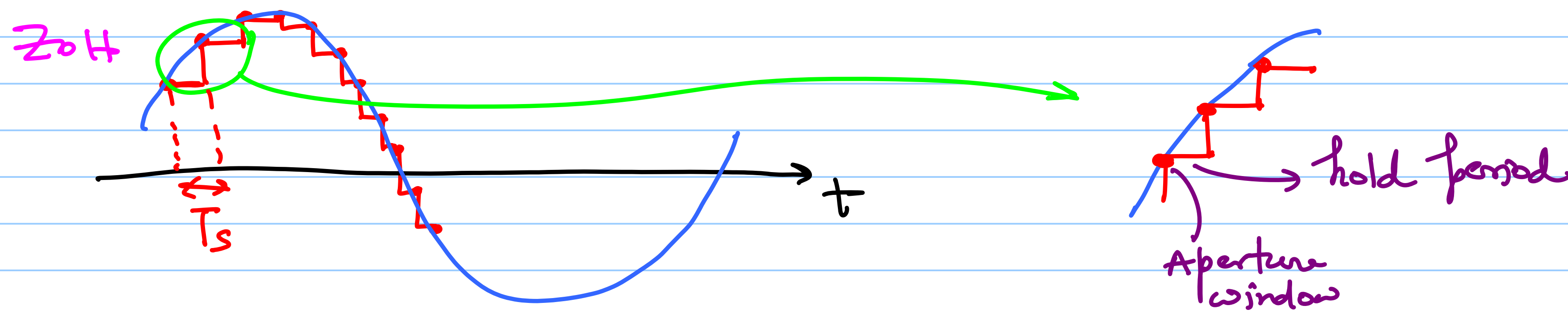
↳ oversampling ratio

* Oversampling relaxes the requirements on AAF
  ↳ could use a lower order filter

Sample-and-Hold

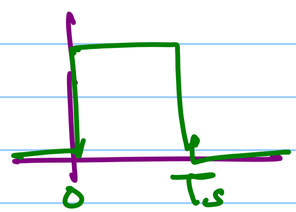
$f_s \to$ sample rate

$\hookrightarrow T_s = 1/f_s$



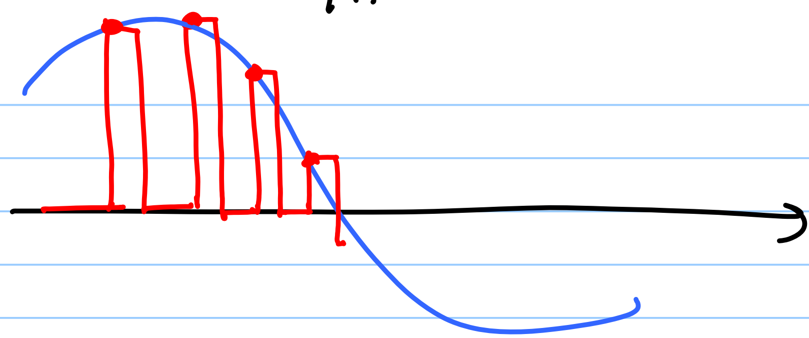
Ideal S/H $\longrightarrow$ aperture window is sufficiently narrow w.r.t T_s

$\hookrightarrow$ Zero-order hold (ZOH)

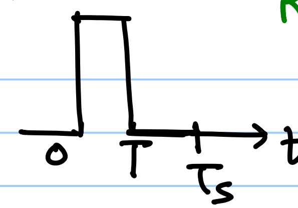


Non return-to-zero (NRZ)

Generalized S/H :



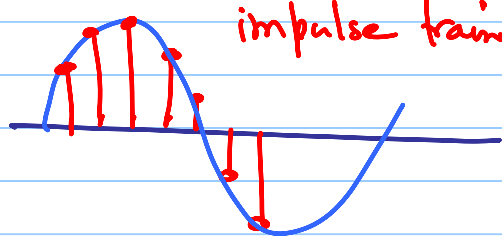
Sample & hold



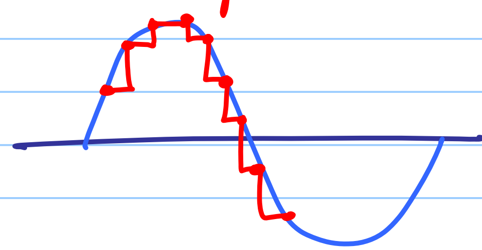
Return-to-zero (RZ) pulse

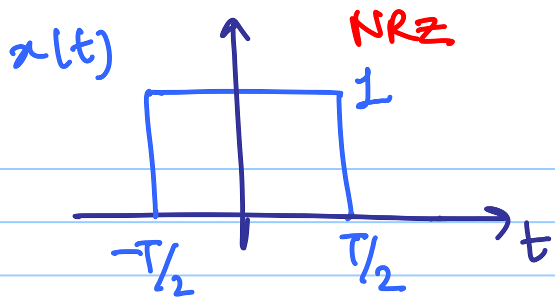
$0 < T \leq T_s$

Ideal Sampling
impulse train

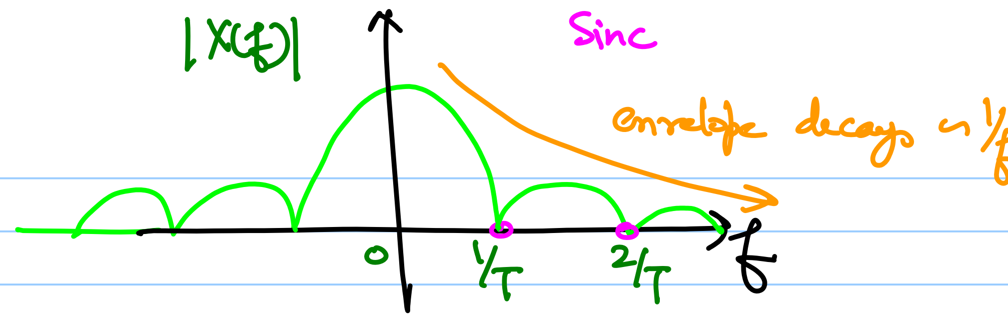


Sample-and-hold





$\xrightarrow{\mathcal{F}}$



$$\mathrm{rect}(t/T) \xleftrightarrow{\mathcal{F}} T \cdot \mathrm{sinc}(fT)$$

$$\mathrm{Sinc}(x) = \frac{\sin(\pi x)}{\pi x}$$

Previously, sampled signal

$$y(t) = \sum_{n=-\infty}^{\infty} x(nT_s) \cdot \delta(t - nT_s)$$

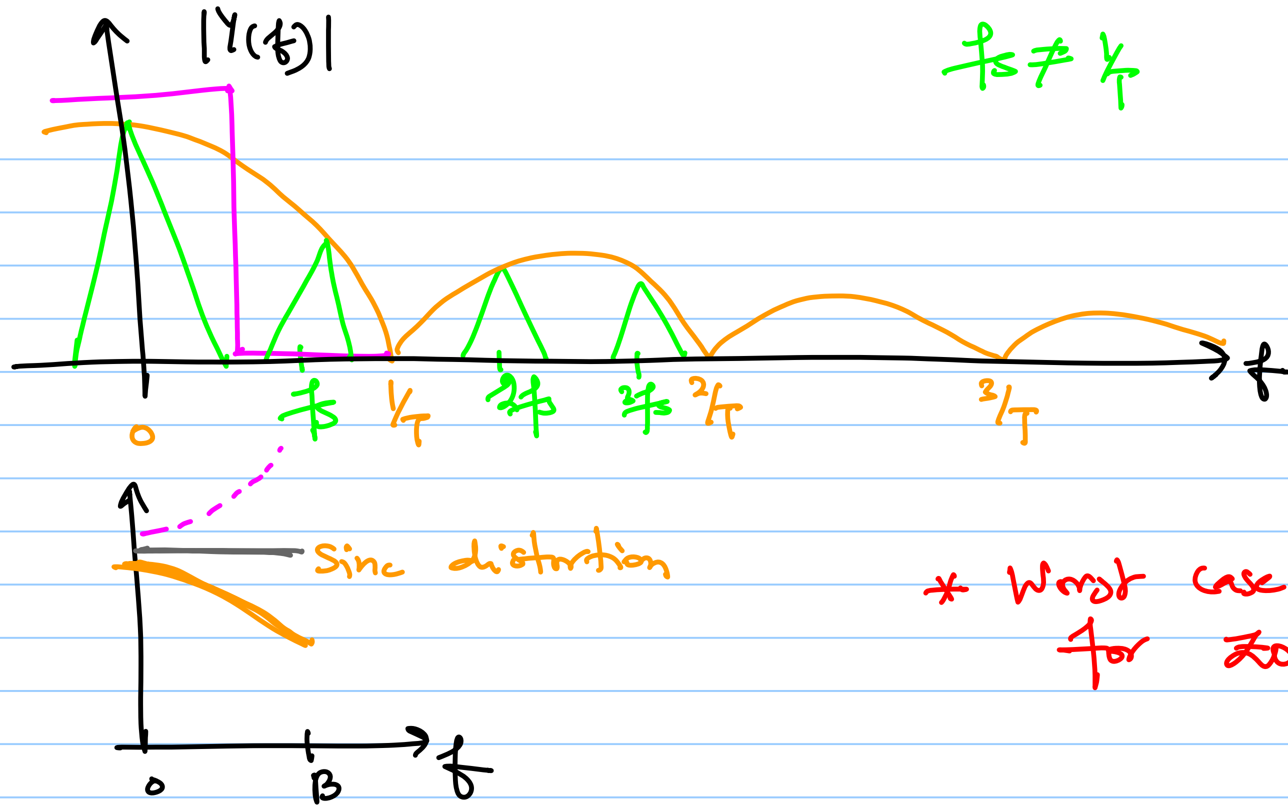
Now, with S/H:

$$y_{S/H}(t) = \sum_{n=-\infty}^{\infty} x(nT_s) \cdot \mathrm{rect}\left(\frac{t - T/2 - nT_s}{T}\right)$$

$$y(t) = \Big[\underbrace{x(t) \cdot \sum_{n=-\infty}^{\infty} \delta(t - nT_s)}_{p(t)}\Big] \circledast \operatorname{rect}\left(\frac{t - T/2}{T}\right)$$

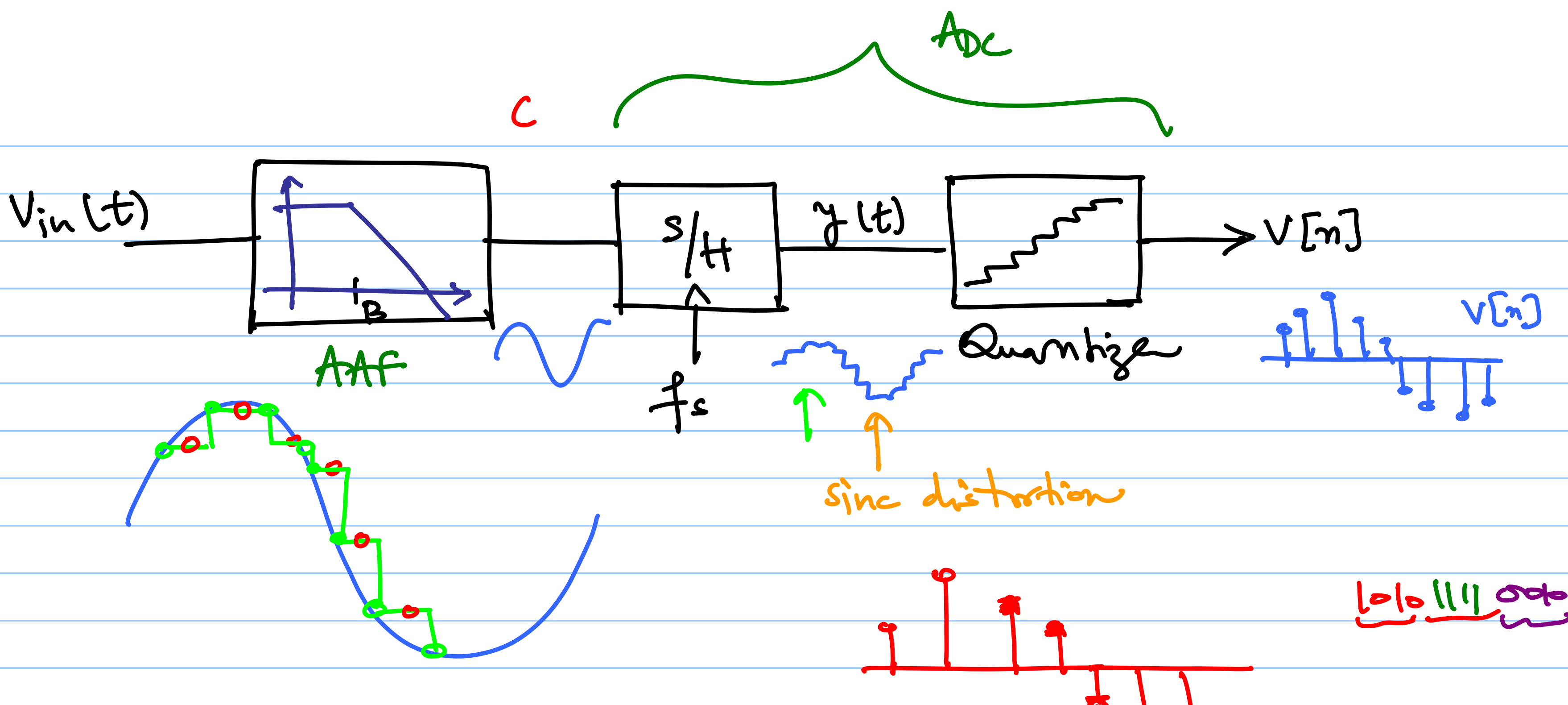
$$Y(f) = \underbrace{\Big[X(f) \circledast P(f)\Big]}_{\text{sampled replicas}} \cdot \underbrace{H(f)}_{\text{distortion due to the S/H}}$$

$$H(f) = T \cdot \underline{\operatorname{sinc}(fT)} \cdot e^{-j\pi f T}$$



$f_s \neq 1/T$

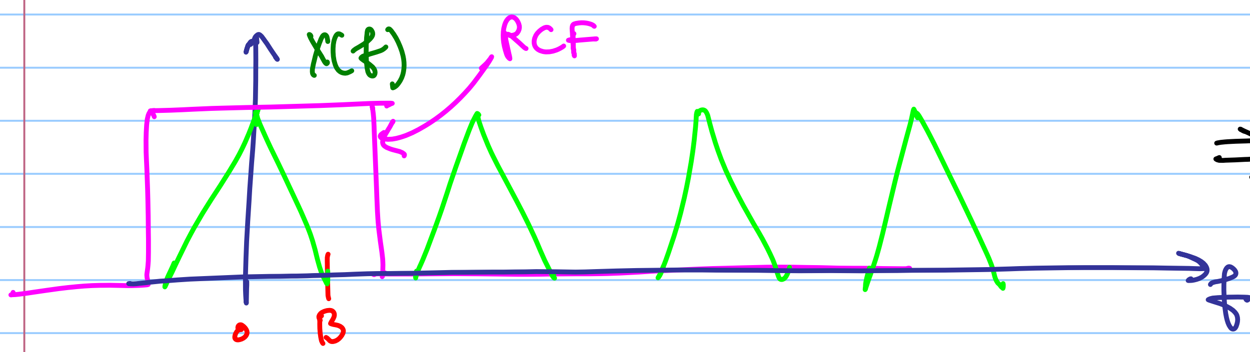
* Worst case sinc distortion for ZOH



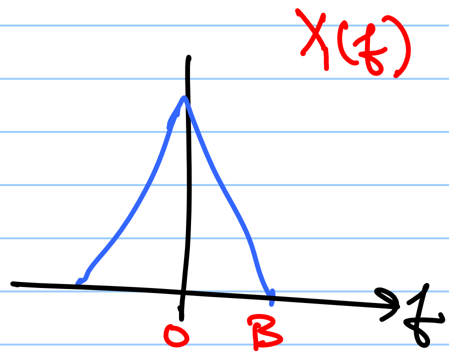
* S/H distortion is not an issue in the ADCs as the quantized value only corresponds to the sampled

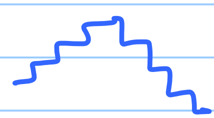
points on the input

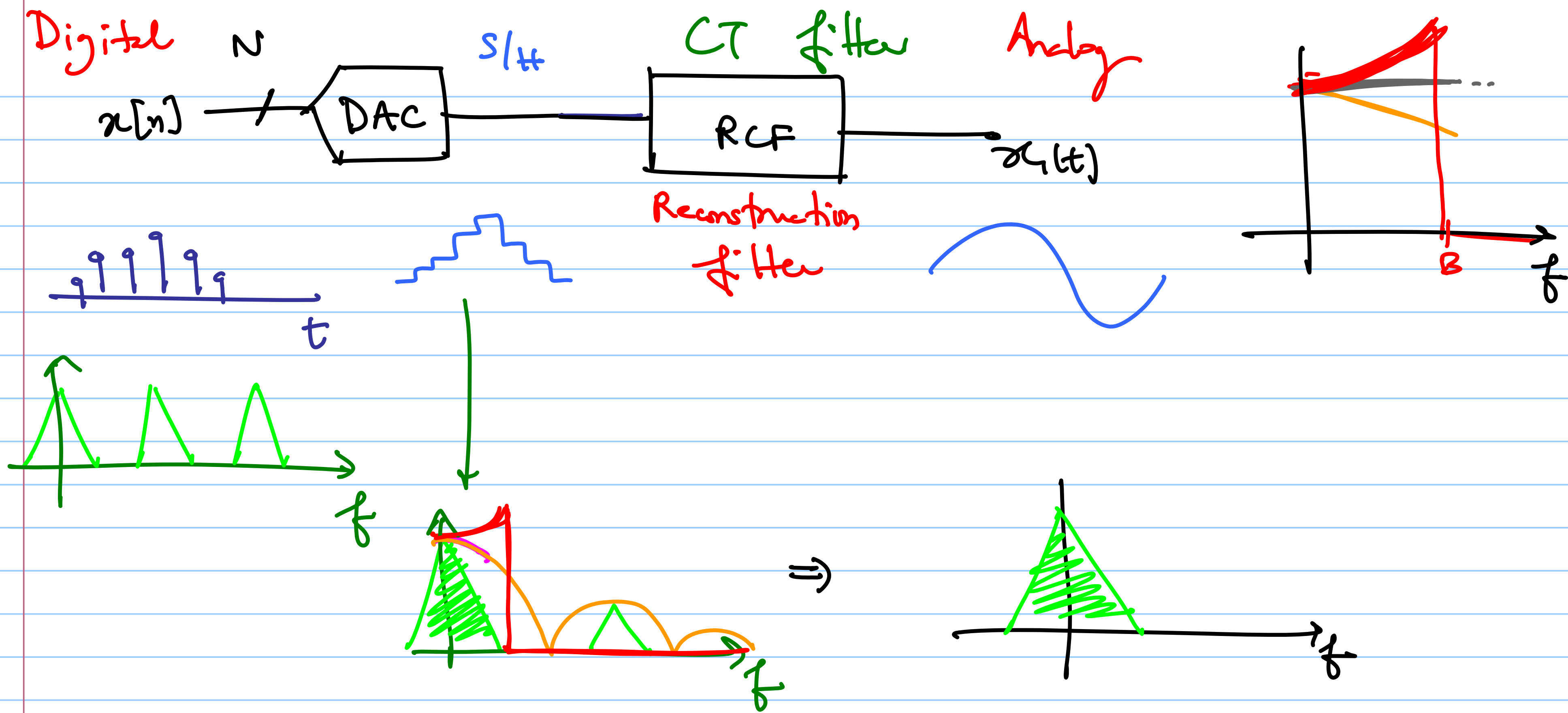
Reconstruction :



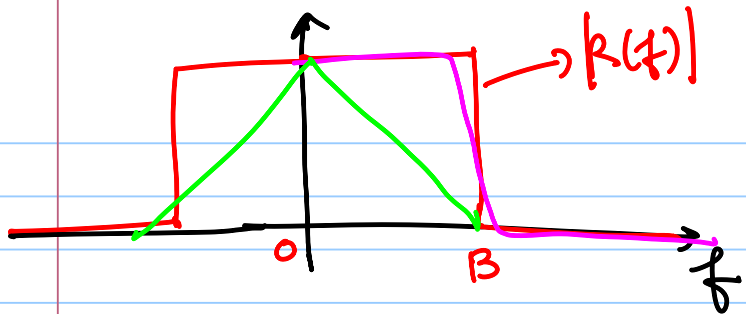
$\Rightarrow$





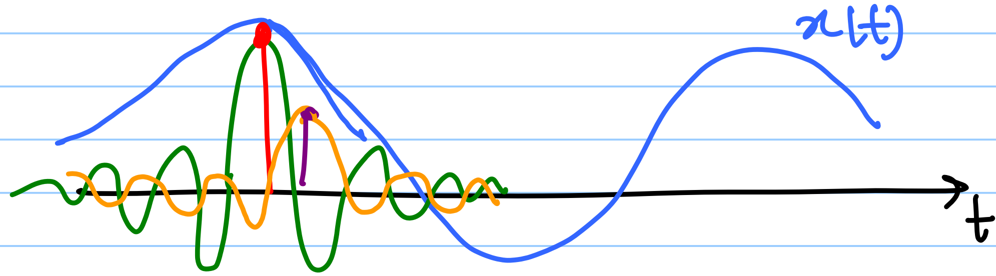


Digital
N
x[n]
DAC
S/H
CT filter
RCF
Reconstruction filter
Analog
x_a(t)
B
f
t
f
f
f



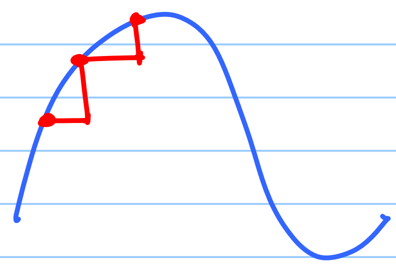
$$Y(f) \cdot R(f) \Leftrightarrow y(t) \circledast r(t)$$

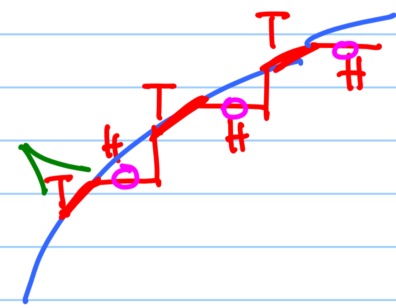
$$R(f) = \mathrm{rect}\left(f/_{2B}\right) \xleftrightarrow{\mathcal{F}^{-1}} 2B \cdot \sin\left(t \cdot 2B\right)$$



$\Rightarrow$ Sinc waveforms overlap and add to interpolate back the desired analog signal

Track-and-Hold





T/H output follows the input during the tracking phase and is held during the hold phase.

acquisition phase

* Distinction between S/H & T/H dissappears at high speeds

* 10 GHz ADC ⇒ T/H